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TITLE: High-temperature characterization of polymers with
HPLC system having
multiple mobile-phase reservoirs

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PARENT-CASE:

This application claims priority under 35 U.S.C. Sec. 119(e) to U.S. Provisional Application Ser. No. 60/080,652, filed Apr. 3, 1998 by Safir et al., which is hereby incorporated by reference for all purposes. This application is a divisional application of U.S. patent application Ser. No. 09/285,333, dated Apr. 2, 1999 now issued as U.S. Pat. No. 6,260,407 to Petro et al. dated Jul. 17, 2001. This application is related to the following U.S. patent applications filed on the date even herewith, each of which is hereby incorporated by reference for all purposes: Ser. No. 09/285,393 entitled "Automated Sampling Methods for Rapid Characterization of Polymers", filed Apr. 2, 1999 by Petro et al.; Ser. No. 09/285,363 entitled "Rapid Characterization of Polymers", filed Apr. 2, 1999 by Safir et al.; Ser. No. 09/285,335 entitled "Flow-Injection Analysis and Variable-Flow Light Scattering Apparatus and Methods for Characterizing Polymers", filed Apr. 2, 1999 by Nielsen et al.; and Ser. No. 09/285,392 entitled

"Indirect Calibration
of Polymer Characterization Systems", filed Apr. 2, 1999
by Petro et al.

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Brief Summary Text - BSTX:

Liquid chromatography is well known in the art for characterizing a polymer sample. Liquid chromatographic techniques employ separation of one or more components of a polymer sample from other components thereof by flow through a chromatographic column, followed by detection of the separated components with a flow-through detector. Approaches for liquid chromatography can vary, however, with respect to the basis of separation and with respect to the basis of detection. Gel permeation chromatography (GPC), a well-known form of size exclusion chromatography (SEC), is a frequently-employed chromatographic technique for polymer size determination. In GPC, the polymer sample is separated into components according to the hydrodynamic volume occupied by each component in solution. More specifically, a polymer sample is injected into a mobile phase of a liquid chromatography system and is passed through one or more chromatographic columns packed with porous beads. Molecules with relatively small hydrodynamic volumes diffuse into the pores of the beads and remain therein for longer periods, and therefore exit the column after molecules with relatively larger hydrodynamic volume. Hence, GPC can characterize one or more separated components of the polymer sample with respect to its effective hydrodynamic radius ($R_{sub.h}$). Another chromatographic separation approach is illustrated by U.S. Pat. No. 5,334,310

to Frechet et al. and involves the use of a porous monolithic stationary-phase as a separation medium within the chromatographic column, combined with a mobile-phase composition gradient. (See also, Petro et al, Molded Monolithic Rod of Macroporous Poly(styrene-co-divinylbenzene) as a Separation Medium for HPLC Synthetic Polymers: "On-Column" Precipitation-Redissolution Chromatography as an Alternative to Size Exclusion Chromatography of Styrene Oligomers and Polymers, Anal. Chem., 68, 315-321 (1996); and Petro et al, Immobilization of Trypsin onto "Molded" Macroporous Poly (Glycidyl Methacrylate-co-Ethylene Dimethacrylate) Rods and Use of the Conjugates as Bioreactors and for Affinity Chromatography, Biotechnology and Bioengineering, Vol. 49, pp. 355-363 (1996)). Chromatography involving the porous monolith is reportedly based on a precipitation/redissolution phenomenon that separates the polymer according to size--with the precipitated polymer molecules selectively redissolving as the solvent composition is varied. The monolith provides the surface area and permeation properties needed for proper separation. Other separation approaches are also known in the art, including for example, normal-phase adsorption chromatography (with separation of polymer components being based on preferential adsorption between interactive functionalities of repeating units and an adsorbing stationary-phase) and reverse-phase chromatography (with separation of polymer components being based on hydrophobic interactions between a polymer and a non-polar stationary-phase). After separation, a detector can measure a property of the polymer or of a polymer component--from which one or more characterizing properties, such as molecular weight can be determined as a function of time. Specifically, a number of molecular-weight

related parameters can be determined, including for example: the weight-average molecular weight ($M_{sub.w}$), the number-average molecular weight ($M_{sub.n}$), the molecular-weight distribution shape, and an index of the breadth of the molecular-weight distribution ($M_{sub.w} / M_{sub.n}$), known as the polydispersity index (PDI). Other characterizing properties, such as mass, particle size, composition or conversion can likewise be determined.

Detailed Description Text - DETX:

The chromatographic column 102 further comprises a separation medium having a stationary-phase within the separation cavity. The separation medium can consist essentially of a stationary-phase or can also include, in addition thereto, an inert support for the stationary phase. The column 102 can also comprise one or more fillers, frits (for separation medium retention and/or for filtering), and various fittings and features appropriate for preparing and/or maintaining the column for its intended application. The particular separation medium to be employed as the stationary-phase is not critical, and will typically depend on the separation strategy for the particular chemistry of the polymer samples of interest, as well as on the desired detection, sample-throughput and/or information quality. Typical stationary-phase media can be a bed of packed beads, rods or other shaped-particles, or a monolithic medium (typically greater than about 5 mm in thickness), each of which can be characterized and optimized for a particular separation strategy with respect to the material, size, shape, pore size, pore size distribution, surface area, solvent regain, bed homogeneity (for packed shaped-particles), inertness, polarity, hydrophobicity, chemical stability, mechanical

stability and solvent permeability, among other factors. Generally preferred stationary-phase include porous media (e.g., porous beads, porous monoliths), such as are suitable for gel permeation chromatography (GPC), and media suitable for precipitation-redissolution chromatography, adsorption chromatography, and/or reverse-phase chromatography. Non-porous particles or empty columns and/or capillaries with adsorptive walls can be used as well. If beads are employed, spherical beads are preferred over other shapes. Particularly preferred stationary-phase media for polymer characterization applications are disclosed in greater detail below, but can generally include silica, cross-linked resins, hydroxylated polyglycidyl methacrylates, (e.g., poly(2-3-dihydroxypropylmethacrylate)), poly(hydroxyethyl methacrylate), and polystyrenic polymers such as poly(styrene-divinylbenzene).